Application of Medium High Hydrostatic Pressure in Preserving Textural Quality and Safety of Pineapple Compote

Nazim Uddin, Yohiko Nakaura, Kazutaka Yamamoto

Abstract**—**Compote (fruit in syrup) of pineapple (*Ananas comosus* L. Merrill) is expected to have a high market potential as one of convenient ready-to-eat (RTE) foods worldwide. High hydrostatic pressure (HHP) in combination with low temperature (LT) was applied to the processing of pineapple compote as well as medium HHP (MHHP) in combination with medium-high temperature (MHT) since both processes can enhance liquid impregnation and inactivate microbes. MHHP+MHT (55 or 65 °C) process, as well as the HHP+LT process, has successfully inactivated the microbes in the compote to a non-detectable level. Although the compotes processed by MHHP+MHT or HHP+LT have lost the fresh texture as in a similar manner as those processed solely by heat, it was indicated that the texture degradations by heat were suppressed under MHHP. Degassing process reduced the hardness, while calcium (Ca) contributed to be retained hardness in MHT and MHHP+MHT processes. Electrical impedance measurement supported the damage due to degassing and heat. The color, Brix, and appearance were not affected by the processing methods significantly. MHHP+MHT and HHP+LT processes may be applicable to produce high-quality, safe RTE pineapple compotes. Further studies on the optimization of packaging and storage condition will be indispensable for commercialization.

Keywords**—**Compote of pineapple, ready-to-eat, medium high hydrostatic pressure, postharvest loss, and texture.

I. Introduction

FRUITS and vegetables are good for health, and diets high in fruits and vegetables are recommended for health-promoting objectives [1] and the consumption of certain fruits and vegetables has historically been considered to prevent or cure ailments ranging from headaches to heart disease [2]. In recent years, dietary guidelines of developed countries recommended to intake half of a fruit or vegetable in each meal [3]. Thus, intake of processed and RTE foods is almost the common trend in the developed and developing countries. Among the processed and RTE foods, fresh-cut fruits and vegetables are an emerging category in the developing countries, because the consumers seek for healthy high-quality food with freshness, and convenience. However, fresh and minimally-processed fresh-cut fruits and vegetables might be contaminated by pathogenic microorganisms derived from a number of sources including farm environment, postharvest handling, and processing. In addition, the contamination level of the pathogenic microbes may vary depending on the fruits and vegetables, and microflora linked with fresh-cut products may differ from one case to another. Thus, safe production of RTE fresh food is being looking for worldwide consumers.

Bangladesh belongs to tropical and subtropical regions, and the people grow diverse fruits and vegetables throughout the year. Pineapple is one of the important agricultural produce, and it ranks 4th in terms of the total production area. However, the postharvest loss is as high as ca. 43%. Therefore, minimizing the postharvest loss by processing pineapple before its deterioration could be revolutionized in reducing postharvest losses and thereby improve the livelihood of pineapple farmers. Furthermore, considering the demand of fresh-cut pineapples, microbial contamination, potentially hazardous to consumers' health, must be minimized for extending shelf life of fresh cut pineapple. Pineapple, among tropical fruits, has a great market potential as a fresh-cut product because of its high sensory characteristics (taste, flavor, and juiciness) and its convenience as RTE foods. However, in fresh-cut fruit processing, typical operations such as peeling and cutting can lead microbial contamination from the outer surface to the tissue by increasing the surface contact and the release of cellular content rich in minerals, sugars, vitamins, and other nutrients, which may promote growth of microorganisms including pathogenic microbes to humans [4]-[6]. Moreover, current commercial fresh-cut pineapple products have a limited shelf life of 5 – 7 days when stored at 1-7 °C, being gradually deteriorated by the development of off-flavors derived from microbiological spoilage and physiological processes [7], [8]. The shelf life of fresh cut pineapple is closely related to its storage temperature [9]. To ensure the safety and quality of processed foods, many processing technologies have been developed which include (i) thermal processes such as microwave and ohmic heating and (ii) nonthermal processes, where heat is not used as a primary mode of processing parameter, such as HHP, pulsed electric field, ultrasonic wave, and high-intensity pulsed light. The nonthermal technologies are primarily being used to replace traditional thermal processing of technologies. Among the nonthermal processing technologies, HHP processing has been commercially used in the food industry since 1990. The technology employs a range of HHP from 400 to 600 MPa at LTs. MHHP in combination with MHT has also being practiced commercially in Japan ranging the pressure and temperature 100 to 300 MPa and 50 to 65 °C, respectively

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[10]. In general, vegetative cells of bacteria such as food-borne pathogens are susceptible to pressure and temperature, whereas their spores show resistance to them. However, MHHP+MHT treatment, germination of spore-forming bacteria can be induced by MHHP + MHT and the germinated bacteria in vegetative state can be heat-inactivated simultaneously. This event is named "suicidal germination" of bacterial spores. MHHP (100 - 300 MPa) activates nutrient germinant receptors, which then facilitate the release of Ca - DPA (chelate of Ca 2+ and dipicolinic acid [pyridine-2,6-dicarboxylic acid]). Ca - DPA triggers a cascade of later germination events: hydrolysis of spore cortex by cortex-lytic enzymes (CLE), degradation of small acid-soluble proteins (SASPs), and generation of ATP in a similar way to a nutrient [11]-[12]. The most important characteristic for MHHP food processors is their heating units. In general, it is technically difficult to insert metal heaters to HHP food processors with vessels allowing a pressurization to 600 MPa. On the other hand, MHHP vessels allow the insertion of metal heaters, and thus MHHP process can be combined with heating at MHT.

The HHP+LT and MHHP in combination with MHT are known to enhance liquid impregnation, while microbial inactivation is expected for both of them. Besides, the effect of those combined methods on the texture has not been clarified sufficiently. For RTE food, the textural quality of the processed product should be kept as close as possible to that of the fresh produce. Since MHHP is combined with MHT temperature, firmness of the products might be lost due to heat. The initial loss of firmness is associated with loss of turgor due to membrane disruption [13]. Conventional thermal process damages food components relating to texture, color flavor and nutrition via enhanced chemical reactions. However, the effects of MHHP in combination with MHT on texture, color, flavor, and other sensory attributes have not been intensively studied for the tropical fruits like pineapple and its compotes.

In this study, the compote of fresh pineapple, - a tropical fruit of Bangladesh was treated with HHP + LT or MHHP + MHT to evaluate the microbiological and textural quality, and safety of fresh cut pineapple. This study also intended to develop safe high-quality pineapple compote as RTE foods.

II. Material and Methods

A. Sample Collection

Fresh 'Dole' pineapples (*Ananas comosus* L. Merrill) were purchased from local supermarkets, and over mature with dry brown leaves or bruised spotted soft fruit were discarded. The fruits were stored at 12 °C prior to be processed in a perforated polyethylene bag to minimize their quality changes [14]. Reagents used for this study were of analytical grade.

B. Pasteurizations of Utensils

All the utensils including cutting boards, knives, containers, and other utensils that come in contact with the fruit during processing were dipped in 200 ppm NaOCl solution for 5 minutes to minimize microbial contamination prior to pouching. To prepare 200-ppm NaOCl solution, 50 ml of 4% (w/v) NaOCl (WAKO, Japan) was filled up with tap water to 10 L. The utensils were dipped in 200 ppm NaOCl solution for 2 minutes, and afterward the materials were turned upside down for another 2 min, and utensils were cleaned with 200 ppm NaOCl manually in the last minute followed by sterile water washed to remove the residual chlorine from the surfaces of utensils. Then, the utensils were turned upside down for 30 minutes in a biosafety cabinet and used for the experiments. The entire working surface was sanitized by sprayed 70% ethanol.

C. Preparation of Syrup

To prepare the syrup for the pineapple compote; sucralose (0.999 g, SU-600, TL4, Japan), citric acid (8.4 g), ascorbic acid (1.2 g), NaCl (1.2 g), and calcium lactate (8.4 g) were dissolved in 1,200 g reverse osmosis (RO) water, and the mixture was pasteurized by boiling for 30 min. The syrup was stored in a refrigerator (~5 °C) before use.

D. Sample Preparation

The whole pineapples were peeled, cored, cut into three parts (top, middle, and bottom), and cut into chunks of ca. 2 cm x 2 cm. The chunks were then immersed in approximately an equal weight of the syrup in a 20 x 15 cm sterilized standing retort pouch, degassed and sealed using a vacuum heat sealer (Tospack, SV 300 GZ), and stored at refrigerator until further use.

E. Sample Processing

The MHHP+MHT treatment (100 MPa) was carried out at 25, 35, 45, 55, and 65 °C for 30 min by using pressurizing unit TFS 2 (max.100 MPa, 2 L; Toyo Koatsu, Japan) and HHP + LT treatment (500 MPa or 600 MPa at 10 °C for 10 min) was carried out by using pressurizing unit TFS6-50 (max. 600 MPa, 5 L; Toyo Koatsu, Japan). The treatment time excludes pressure come-up and come-down times. The thermal treatments at 25, 35, 45, 55, 65, 75, and 95 °C were done in the chamber of TFS 2 at ambient pressure (0.1 MPa). Immediately after each treatment, pouches were immersed into an ice water bath.

The schematic diagram of sample preparation and processing is presented in Fig. 1.

1. Enumeration of Microbial Survivors

The pineapple chunks (ca. 40 g) were poured in stomacher bag containing 40 ml of 0.9 % sterile saline water (w / w) and stomached for 60 seconds in a stomacher (Stomacher, Promedia, SH-IIM, ELMEX, Japan) at 120 rpm. The crushed filtrate was poured into 50-ml tubes. Serial dilutions were made using 0.9% sterile saline solutions. The diluted and non-diluted stomached treated samples were then surface plated on standard ager (Nissui, Japan) plates. The plates were then incubated at 37 °C for 24 h (max.72 h) and then the number of colonies was counted as colony forming unit (CFU). The analysis was repeated four times (n = 4) and the number of survivors was expressed with standard deviations.

2. Texture Analysis

Texture of the pineapple samples was analyzed by measuring mechanical properties in a uniaxial compression mode using a creep meter (RE - 33005, YAMADEN, Japan) with a probe (40 mm φ). Pineapple chunk was shaped into a cylinder by cork borer and the cylinder was sliced into discs of 15 mm in diameter. The sample was compressed at a rate of 0.5 mm/s until the initial height was deformed by 30 %. The data on stress-strain curve of all processed samples were transferred into Microsoft Excel 2000, and a linear regression analysis was carried out. The peak force (N = gf x 0.001 x 9.80665) and the initial elastic index (MPa) were calculated as indices of texture. Peak force was determined as the maximum force of a compressive curve. A typical stress-strain curve is shown in Fig. 2. In general, mechanical response of plant tissue initially shows a linear stress-strain relationship or an elastic response till a critical deformation level. The straight-line slope gives the small strain or initial modulus [15]. Therefore, the initial elasticity curve (modulus curve) was calculated from the slope (tangent) of the linear zone (in this study: 0.0499 to 0.1499, R2 ≥ 0.97) of the stress-strain curves with a maximal regression coefficient. The measurement procedures were repeated 4 times (five chunks measurement) and the data were averaged.

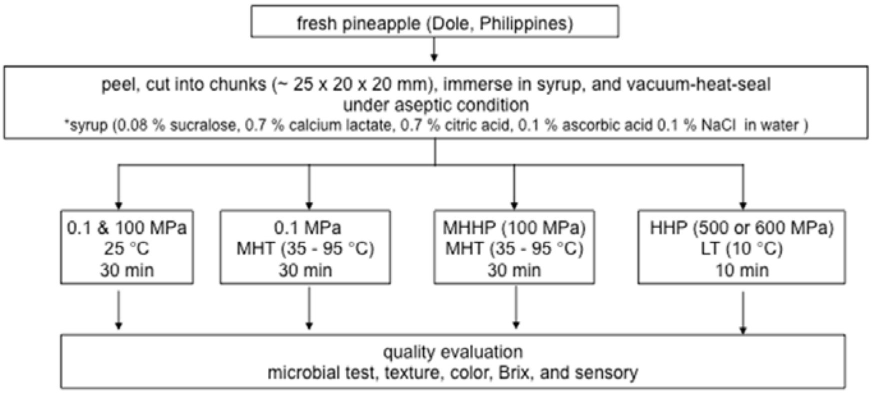


Fig. 1 Schematic diagram of sample preparation and processing

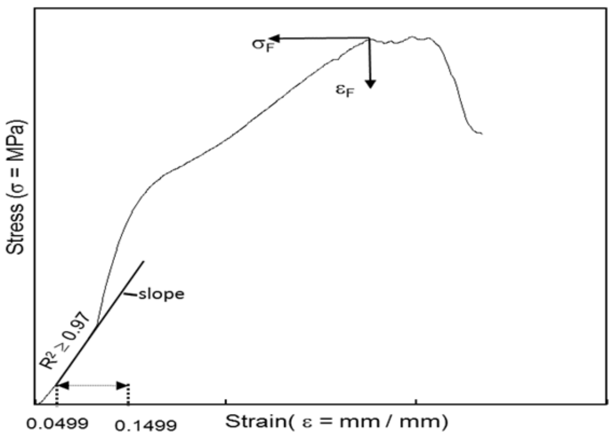


Fig. 2 General course of uniaxial compression in plant tissue

3. Color Measurement and Sugar Content

Color of fresh and processed samples was measured using a handy colorimeter (CR-400 Chroma-meter, Minolta, Japan). The instrument was calibrated with a standard white plate at D_{65} illumination (Y = 94.3, x = 0.3156, and y = 0.3324) before a series of measurements. The parameters L*, a*, and b* represent brightness, hue range of the colors red (+) and green (-), and hue range of colors yellow (+) and blue (-), respectively. Measurements were repeated three times on the surface of each treated pineapple chunk and the data were averaged. Chroma [16] and browning index [17] were calculated using the following equations, respectively.

$$\text{Chroma} = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$\text{Browning index} = (X-0.31) / 0.17 \times 100 \quad (2)$$

where X= (a* + 1.75 L)/(5.645 L + a* -3.012 b*)

The sugar content of the fresh or processed sample was evaluated as Brix using a handy Brix meter (PAL 1, ATAGO, Japan).

4. Electrical Impedance (EI) Analysis

During processing of pineapple compote, degassing, heating, MHHP treatment, and thereafter, the cell structure and membrane may change or affecting the texture. The EI analysis is widely used to estimate the physiological state of various biological tissues for its simplicity and effectiveness. Therefore, EI of processed pineapple tissue was measured to understand the texture retention and degradation according to the user manual shown in (Fig. 3). Briefly, pineapple chunks (20 x 20 x 20 mm) were mingled and immersed in approximately an equal weight of the syrup in a 20 x 15 cm standing retort pouch. The degassing (+ dg) was carried out by a vacuum heat sealer (Tospack, SV 300 GZ). The samples with non-degassing (-dg) was prepared in a way that air bubble was removed by hand and minimized in the pouch, and then the pouch was sealed by a heat sealer (P-300, 100 V, 360 W, Fuji Impulse, Japan). After sealing, the samples were stored at 4 °C until further processing. To maintain the uniformity of the processing, thermal treatment was carried out by using TFS 2 (max.100 MPa, 2 L; Toyokoatsu, Japan) machine. The vessel of TFS 2 was filled with RO water up to the mark and set at a desired temperature (e.g. 25 or 65 °C), and after attaining the temperature, samples were then kept inside the vessel and closed the lid. After confirming the desired temperature on the monitor screen of TFS 2, the samples were then treated up to 30 min. The treatment time excludes pressure come-up and come-down times for the MHHP treatment. Immediately after each treatment, pouches were immersed into an iced water bath for 30 min for come–down temperature. A total of eight treatments combination were processed (Fig. 3). The processed samples were tested for the electrical impedance by a LCR tester (3352-50, HIOKI, Japan) with two parallel clip test probes spaced 17 mm apart at 50 different frequency points (logarithmic frequency intervals) over frequency range of 100 Hz to 1 MHz under measuring voltage of 1 V at 20 °C, and the data were recorded by a computer automatically. Nine samples were tested for each condition and average values were utilized to depict Cole-Cole and Bode plots. In Cartesian form, complex impedance Z is defined as;

$$Z = R + jX \quad (3)$$

where the real part of impedance is resistance (R) and imaginary part is reactance (X).

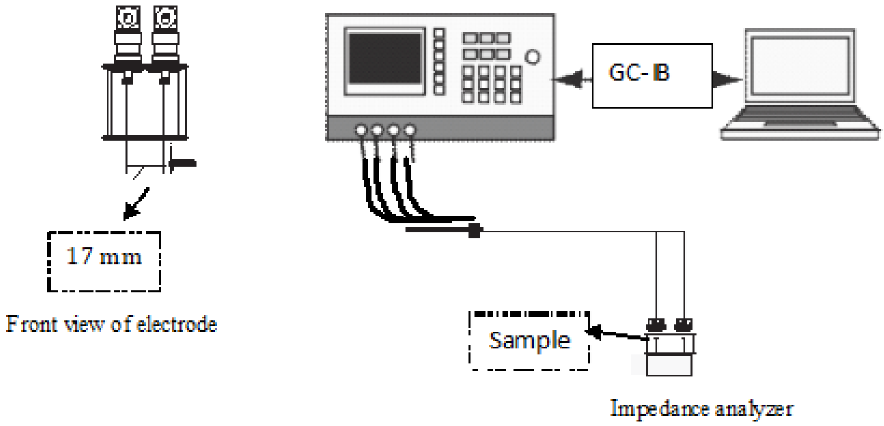


Fig. 3 A system of electricimpedance

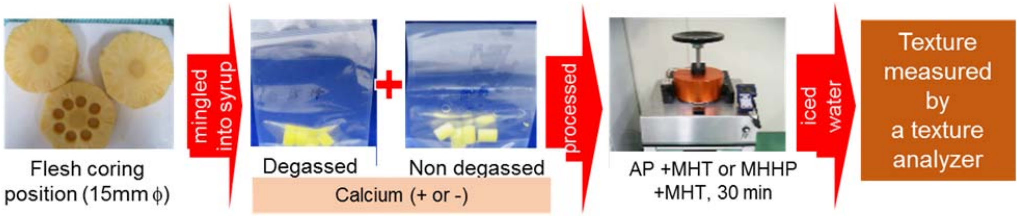


Fig. 4 Processing method of pineapple flesh

5. Evaluation of Ca and Degassing (dg) on Pineapple Compotes Texture

After peeling the pineapple, a disc (15 mm ϕ) of pineapple flesh was prepared by using a cork borer. The flesh was then immersed in approximately an equal weight of with (+) or without (-) Ca syrup in a 20 x 15 cm standing retort pouch. The degassing (+ dg) was carried out by a vacuum heat sealer (Tospack, SV 300 GZ). The non-degassing (-dg) was done in a way that no air bubble was remained inside and then the pouch was sealed by a polysealer (P-300, 100 V, 360 W, Fuji Impulse, Japan). After sealing samples were stored at 4 °C until further processing. To make a uniform sample, the four 15 mm ϕ discs from a cylindrical pineapple fleshes from each position were placed for counter treatment [e.g. MHHP+MHT (+Ca, +dg) and AP+MHT (+Ca, +dg)] (Fig. 4).

Texture of the pineapple samples was analyzed by measuring mechanical properties in a uniaxial compression mode using a Creep meter (RE - 33005, YAMADEN, Japan) with a probe (40 mmϕ). The sample was compressed at a rate of 0.5 mm/s until the initial height was deformed by 30 %. The measurement procedures were repeated 4 times (four measurement), and the data were averaged.

6. Sensory Evaluation

Triangle tests were used to determine if the MMHP+MHT could have an impact on the sensory quality of fresh-cut pineapple chunks. The tests evaluated potential differences between samples treated by ambient pressure (AP) and temperature (reference condition) to those treated by AP+ MHT or MHHP+MHT. The procedures followed were according to those described in ISO 4120:2004 (Sensory analysis – Methodology – Triangle test) [18]. Pineapple chunks (treated or fresh) were transferred into plastic containers labeled with number codes. The plastic containers were closed and kept at room temperature (25 °C) before the triangle tests were performed. The sensory evaluation was performed in a purpose-built sensory analysis by seven untrained assessors (three female assessors and four male assessors) and they are the laboratory members. For each test three coded samples, of which one was different from the other two, were presented to the assessors. The assessors recorded their responses on paper scorecards. Each assessor was asked to identify the different sample based on color, odor and taste. The assessors were instructed to only assess the taste of the samples if they thought the color or the odor were still acceptable. When the assessors finished the triangle test, they were asked to select the sample(s) that they preferred and to indicate the reasons why they considered a sample to be unacceptable or preferable. The test was always performed within 30 min after transferred to plastic containers in a single repetition.

III. Results and Discussion

A. Microbial Analysis

The combined process of MHHP (100 MPa) + MHT (55 or 65 °C) for 30 min has successfully inactivated the microbes in the compote to a nondetectable level as well as the HHP + LT (10 °C) processes (Fig. 5). The process at ambient pressure (0.1 MPa) and 55 °C was less effective than the MHHP +MHT process at 55 °C, while the heat processes at 0.1 MPa and 45 °C and 65 °C was comparable to the MHHP + MHT processes at 45 and 65 °C, respectively. In the pineapple compote, efficient bacterial inactivation, probably accompanied with suicidal germination, was observed when treated by MHHP+MHT (100 MPa at 55 °C and 65 °C for 30 min) treatments. It was indicated that MHHP + MHT process for the production of pineapple compotes enhanced the microbial inactivation in combination with heating at 55 °C and higher.

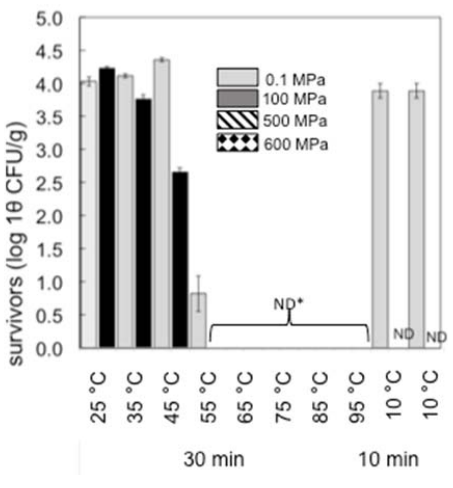


Fig. 5 Inactivation of microbial population by MHHP + MHT and HHP +LT treatments; Values are means ± SD of the four experiments with triplicate determinations per experiment. ND=nondetecable

B. Texture Analysis

Pineapple possesses a complex fruit anatomy and maturity pattern, and its fruit flesh is non-uniform in texture. Therefore, its texture is influenced greatly by maturation, storage, and processing temperature. Assessing Texture revealed the freshness of processed pineapple products. Several factors including cell turgor, cell wall resistance, tissue direction, densities of the cell during packaging, pectic substances and their sensetivities to biochemical and chemical modifications, degree of methoxylation, β-elimination, pH, ferulic acid (pH lowering substance), and Ca+ may contribute to the texture of fruits and vegetables [19], [20]. The result revealed that the peak force (N) and initial elasticity index (MPa) have significantly decreased at ambient pressure (0.1 MPa) and elevated higher temperature (Figs. 6 A and B). The pineapple compote processed by MHHP + MHT (100 MPa and 55 or 65 °C for 30 min) or HHP + LT (500 or 600 MPa and 10 °C for 10 min) retained its texture.

The peak force (N) and initial elasticity index (MPa) for pineapple compote processed under ambient condition (25 °C) were around 10.5 and 0.40, respectively, whereas the compotes treated at higher temperatures have shown significantly reduced values. On the other hand, the pineapple compotes processed by MHHP +MHT (35 to 95 °C) have lost the fresh texture, but their values were comparable with those processed ambient pressure. The peak force and initial elasticity index of pineapple compote treated by HHP + LT have also shown retained textural properties as compared to those processed by MHHP + MHT. The values for those by MHHP+MHT, however, were comparable with those by heat at a lower temperature, indicating that the texture degradations by heat were suppressed under MHHP. These results comply with those reported on pineapple [21].

To understand the deleterious textural effects in plant tissue by processing condition, Ca and degassing experiment has been carried out and results are presented in Figs. 7 A and B. Degassing process reduced the hardness and elasticity significantly, while processed MHT, but MHHP + MHT retained the hardness and elasticity comparable with MHT. Ca contributed to be retained hardness in MHT and MHHP+MHT processes.

1. Electrical Impedance Measurement

Electrical impedance measurement revealed that degassing process contributed to the damage to the cell structure. MHHT+MHT processes at 25 and 65 °C after degassing showed a less damage than ambient degassing processes at both temperature (Figs. 8 A and B). Pineapple flesh tissue is not homogeneous in nature. However, during processing of pineapple compotes degassing (with vacuum sealer) was done, and vacuum impregnation (VI) has been occurred via vacuum osmotic dehydration (VOD) very rapidly. VI leads to a faster osmotic process due to coupled action of hydrodynamic mechanism and deformation relaxation phenomena [22]. In this process, gas-liquid exchange causes a rapid change of overall sample composition that modifies the process driven force at the very beginning of the process, while pores remain full of liquid. In VI, the penetration of external liquid is caused by combined effect of capillary action and pressure gradient.

VI also causes the structural changes in the tissue different than those caused by osmotic processing. On the other hand, non-degassing process is partial osmotic dehydration and takes more time to be filled their pores by the liquid less abusing to cell membrane over VOD.

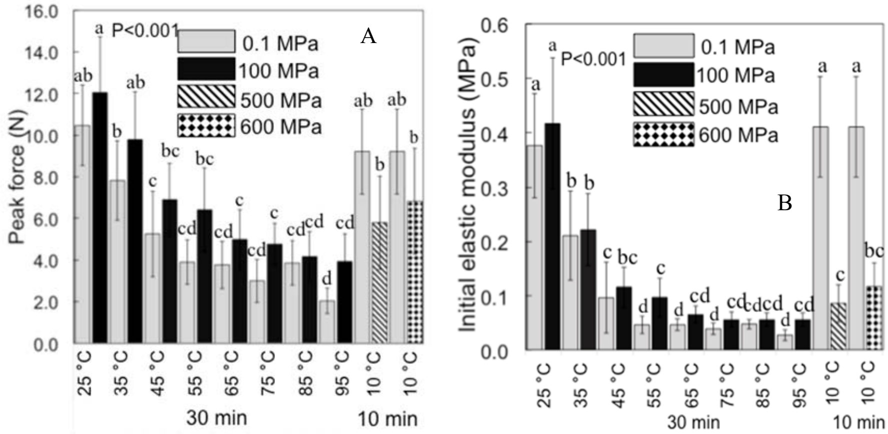


Fig. 6 Peak force (A) and initial modulus/ elasticity index (B) calculated from the stress-strain curves; Statistical differences were analyzed by 1-way ANOVA, and means are separated by a Tukey`s HSD test (≤ 0.05), values represented by the same colored bars that have same letters indicated on top of each bars showed no significance difference.

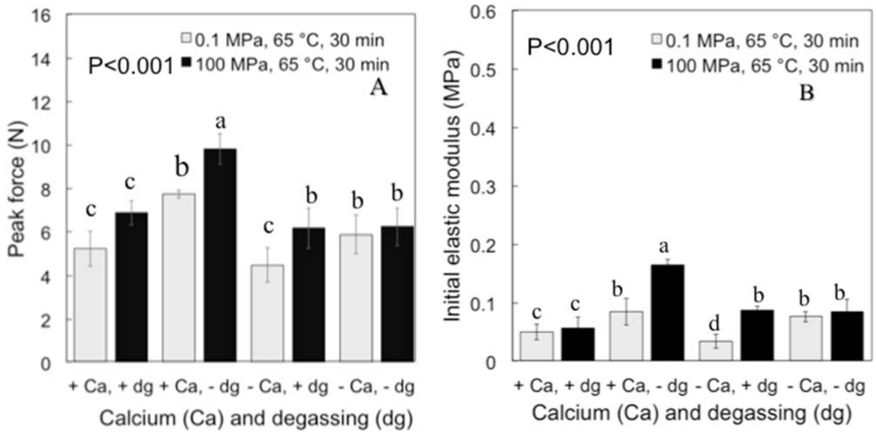


Fig. 7 Peak force (A) and initial modulus/ elasticity index (B) calculated from the stress-strain curves; Statistical differences were analyzed by 1-way ANOVA, and means are separated by a Tukey`s HSD test (≤ 0.05), values represented by the same colored bars that have same letters indicated on top of each bars showed no significance difference

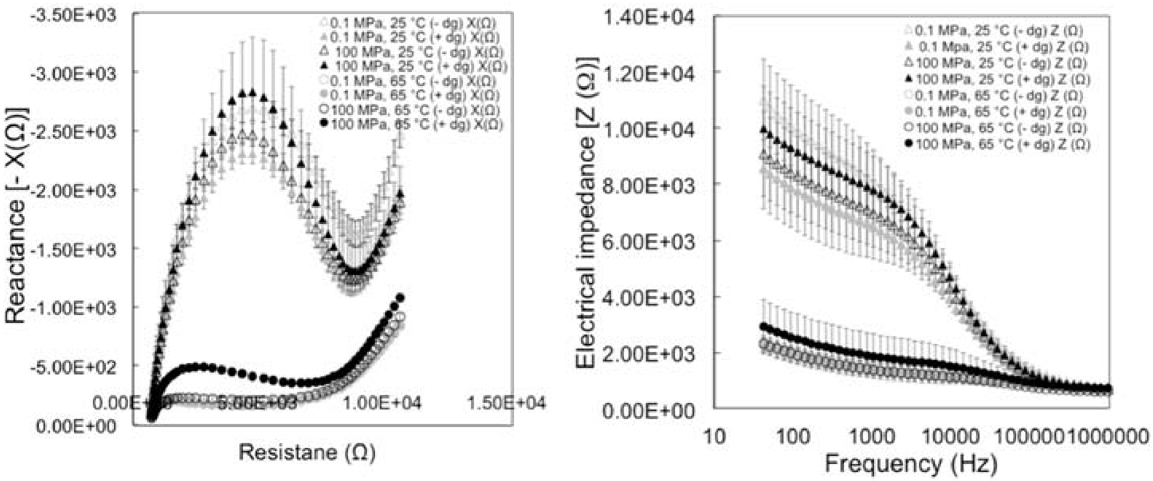
HHP also affects the cell structure, by disrupting the parenchyma tissue. The cell collapse and none of the intercellular spaces were filled with gas and complete disorganization occurred. The vascular tissue, the cells were cemented instead of being filled with gas, and thus give the rigid form of the tissue which reflects on cell structure and texture [23]. Moreover, at elevated temperatures, high methoxyl pectin is prone to non-enzymatic conversions: depolymerization and demethoxylation. A temperature rise may lead to a stronger acceleration of β-eliminative depolymerization than of demethoxylation. Thus, β-eliminative depolymerization is accepted to be one of the main processes for the extensive softening of low-acid fruits and vegetables during heat treatments [24]. Moreover, low methyoxyl pectin strengthens the tissue by forming cross-links with Ca ions, and HHP (500-700 MPa)+HT (90-115 °C) influences the process to improve or retain texture by stopping or retarding the β-elimination process [17], [25].

In this study, Ca at MHT could not contribute to texture retention, but in combination with MHHP + MHT+ degassed retained the texture. The improve texture was observed at non-degassed condition. It is known that texture is the output of cell structure and turgor pressure. In the non-degassed condition, although Ca was avoided, gas liquid interaction increased the elasticity of the cell wall thus improves the textural properties.

In the Cole-Cole plot, electric impedance values of no degassed/VOD were bigger and higher respectively due to less damage as compared with degassed. On the other hand, MHHP in combination with degassed improves the cell size thus bigger plots with higher value respectively, indicated the cell disrupted by degassed was suppressed my MHHP. While pineapple flesh processes at MHT in combination with non-degassed Cole-Cole plot almost similar to degassed but

MHHP+MHT processed suppressed the damage. It is known that application of hydrostatic pressure (100-800 MPa) causes permeabilization of the cell structure [26], [27]. The osmotic dehydration of HHP treated pineapple is faster than untreated fresh [28] and confirmed by using HHP and electric impedance as a measuring tool [29].

The pineapple fruit contains high endogenous ferulic acid among the monocotyledons [30] and the fruit is highly acidic in nature. In the thermally-processed pineapple chunks, it may be anticipated that a temperature rise at ambient pressure could accelerate the β-eliminative depolymeration more than the demethoxylation leading softening the tissue. On the other hand, as for, the pineapple compotes processed by MHHP + MHT it may be anticipated that the β-eliminative depolymerization process could have retarded or stopped and demethoxylation might have stimulated successively. It is probable that Ca+ cross-linked with demethoxylated pectin gave strength to the tissue. In this study, the aforesaid process might help retain the texture of the MHHP + MHT and HHP + LT processed pineapple compote.



(A) (B)

Fig. 8 Representative Cole-Cole plots (A) and electrical impedance (B) characters of pineapple tissue Values are means of 9 samples of each

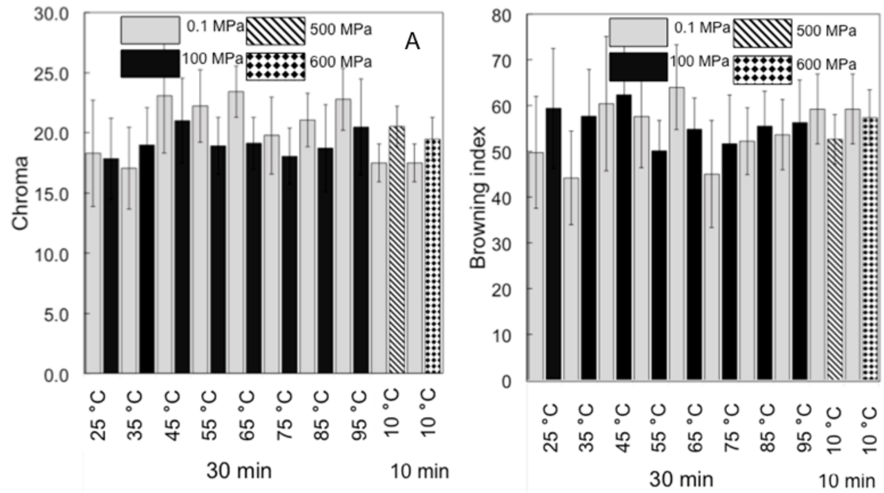


Fig. 9 Differences in chroma (A) and browning index (B) calculated from L*, a*, and b* values. Values are means ± SD of the four experiments with triplicate determinations in each chunk and 5 chunks per experiment

TABLE I
COMPARISON OF SENSORY CHARACTERISTICS OF TREATED AND NO-TREATED PINEAPPLE COMPOTES

Sensory Characteristics	Fresh	Boiled (>95 °C, 30 min	100 MPa, 55 °C, 30 min	100 MPa, 65 °C, 30 min
Taste	Sweet	Slightly sour	Sweet	Sweet
Color	Yellowish	whitish	Yellowish	Yellowish
Flavor	Natural	Cooked-like	Near natural	Near natural
Texture	Fibrous	Comparatively soft	Fibrous	Fibrous
Overall acceptability	Like very much	Dislike	Like very much	Like very much

C.Chroma, Browining Index and Sugar Content Measurement

Chroma is considered as an index for intensity or saturation of color [16] and is used to evaluate the degree of difference in color. Chroma values of thermally-processed compotes increased after thermal treatments at ambient pressure, whereas the pineapple compotes proscessed by MHHP + MHT or HHP + LT have shown comparable chroma values to the fresh one (0.1 MPa, 25 °C, 30 min) (Fig. 9 A). The results indicate that the pineapple compotes processed by MHHP+ MHT, and HHP+LT may retain the intensity of color the fresh pineapple compotes. Browning may result from either enzymatic or non-enzymatic oxidation of phenolic compounds. However, once cell walls and cellular membranes lose their integrity, enzymatic oxidation proceeds rapidly. As for pineapple compotes browning was observed not significant. In the study of thermally-processed pineapple juice [31], it is reported that destructuion of carotenoids and non-engymatic Maillard reaction are responsible for change in the chroma and increased browing index, respectively.

The processed pineapple compotes by MHHP + MHT or HHP + LT retained the chorma values and browning indices comparable with those of the fresh ones. Therefore, in terms of the attractiveness and retained fresh color, the pineapple compotes processed by MHHP + MHT and HHP + LT can be selected for further study. The soluble solids measured as Brix (%) did not change remarkably when the compotes were processed (Fig. 10). The Brix value of each processed pineapple compote was comparable with that of fresh compote.

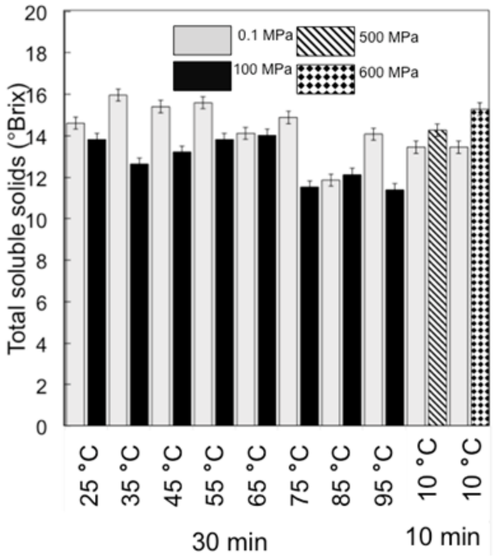


Fig. 10 Changes in total soluble solids after treatments. Values are means ± SD of four trials with 5 determinations per trials

D.Sensory Evaluation

Table I denotes the compiled comments of evaluators on the sensory evaluation of the pineapple compotes. The evaluators were in favor of the pineapple compotes processed by MHHP +MHT in terms of taste, color, flavor, and overall acceptibility. In constrast, the conventional thermally-processed pineapple compote (boiled) was slighly sour, whitish, smelling cooked odor, and less favored.

IV. Conclusions

Pineapple is one of the most important commercial and delicious tropical fruits. Thermal treatment is generally applied to extend the shelf life of pineapple fruit products. However, the thermal process does not ensure the freshness of pineapple as RTE products. MHHP+MHT and HHP+LT are the potential alternatives among the nonthermal processing technologies, which may ensure both the microbial safety and sensorial qualities. In this study, the pineapple compotes processed either by MHHP+MHT or HHP+LT process were effective for ensuring microbial safety and retaining physical (texture), chemical (color, TSS), and sensory (flavor, taste) properties maximally. The thermally-processed pineapple compotes have lost the freshness to a large extent.

Therefore, pineapple compotes processed by MHHP+MHTs or HHP+LT may have potentials in the pineapple growing county like Bangladesh, where RTE food market is emerging. However, optimization of storage condition, packing, and other relevant quality parameters should be further studied for commercialization. Moreover, since the postharvest loss minimization is the priority issue in the developing countries, application of MHHP+MHT and HHP+LT treatments to other fruits and vegetables may help to reduce postharvest loss and increase the employment opportunity. Taking into account the optimized condition for the pineapple processing, other fruits and vegetables may be processed as well.

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